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Smart grid opportunities and applications in Turkey

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ABSTRACT

A smart grid is a system that uses information and communication technologies to integrate, in an intelligent way, all users connected to the electrical power system considering their behaviour and actions. For this purpose, information about the electrical network, such as the current, the voltage or the power, is gathered together over time so that the behaviour of suppliers and consumers can be observed and automatically coordinated. Smart grids are becoming a significant part in the configuration of future electrical power systems. A lot of research has been done on using smart grids to achieve highly efficient and user-friendly electrical power systems. Many new methods have been introduced to solve the difficulties energy providers face when transforming conventional electrical networks into smart grids. These difficulties include the integration of renewable energy and different grid systems at national and international levels due to changes in frequency, voltage and in the synchronisation mechanism.

This paper provides an outline of the European smart grid projects and gives an overview of the current infrastructure and smart grid applications of the Turkish Electricity Production System Operator (EUAS), Turkish Electricity Transmission System Operator (TEIAS), and Turkish Electricity Distribution System Operator (TEDAS). In this paper the feasibility of the further steps required is described and some assessments are made and suggestions given on smart grid developments in general.

Contents

1. Introduction

Intelligent equipment that inform and warn operators when they are experiencing any kind of operational problem can be integrated with the development and widespread use of communication technology. Problems occurring on the grid can be evaluated by analysing defects at the failure point. It has become more important to identify

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faults without letting the grid fail. Therefore many studies have been carried out on how to improve energy quality. As people have awoken to the need to monitor network currents, voltages, harmonics and power outages, and as efforts to improve energy efficiency have been stepped up, the potential of smart grids has become clear. One example is the remote monitoring of low voltage (LV) networks that allows operators to fix problems instantly.

An electrical network is an interconnection that permits the delivery of electricity from suppliers to consumers. It consists of power stations, storage facilities, transmission lines, distribution lines, transformers, power switches, measuring equipment and loads. According to a recent survey on smart grids, research focuses mainly on three subjects, namely infrastructure, management, and protection. Therefore, a modern set of electrical power infrastructure can be considered as a smart grid. The targets of smart grids are to increase the efficiency and the reliability using automated control, high-power smart converters, modern communications infrastructure, intelligent sensing and metering technologies, and contemporary energy management techniques, all based on the optimisation of demand, intelligent protection, and energy and network accessibility [1]. An integrated and fully automated smart grid approach allows both system operators and consumers to improve the reliability, efficiency and asset utilisation of the power system in a protected way [2]. Smart grids are defined as integration of information and communication technologies (ICT) into the grids to monitor and regulate the demand and the power generation [3,4]. The idea of smart grids has started to progress more rapidly with the improvements in the communication technologies. Specifically the two-way communications has become a fundamental aspect of smart grids [5].

A power system with smart communication allows information to flow punctually, reliably and adaptably, serving millions of customers and powering the needs of the digital economy [1]. The smart grid should be also considered as being a tool to help save energy not only as a self-managing system. Smart grid technology makes it possible to connect more environmentally friendly, but may be extremely in non-uniform pattern, renewable energy resources such as solar, wind, hydropower, biomass, and geothermal, energy sources to the grid [4]. They make it possible for the grid to be self-managing, for the number of failures and outages to decrease, and for the energy grid to last longer. Through bidirectional energy flows, consumers' participation as producers (prosumers) increases. The system becomes more stable and additional benefits, such as balancing peak demand, are provided.

To support the transition to a smarter grid, it is crucial that smart project information is shared. To this aim, the Joint Research Centre of the European Commission regularly monitors and catalogues smart grid projects in Europe to bring together lessons learned and assess current developments [6].

This paper gives an overview of smart grid projects in Europe and provides detailed information about the current infrastructure and smart grid applications of the Turkish electricity sector. The paper also discusses the historical development of the Turkish Electricity Production System Operator (EUAS), Turkish Electricity Transmission System Operator (TEIAS) and Turkish Electricity Distribution System Operator (TEDAS). Moreover, the paper makes some general assessments and gives suggestions on smart grid projects in Turkey in light of the lessons learned from other European projects.

2. Overview of smart grid projects in Europe

Smart grids have been a key subject in the European energy market since it became necessary to integrate different types of renewable energy resources to the grid system and to transform and transfer energy between different grids. Many companies, institutions, universities and researchers have been studying smart grids to increase the reliability, efficiency and robustness of the grids to provide cheap and sustainable energy.

A key issue in supporting the transition to smart grids is the sharing of information and projects outcomes between consumers, researchers and companies. For this reason, the European Commission's Joint Research Centre (JRC) frequently monitors and catalogues smart grid projects in Europe to bring together lessons learned and assess current progresses [6].

This inventory focused on the following subjects;

- Smart grid projects in terms of investment, budget and scale;
- Private assets and funding of smart grid projects;
- Geographical distribution of activities and budget;
- Multinational smart grid projects and their associative relations;
- The range and type of organisations in the smart grid landscape;
- Smart grid applications;
- Smart metering;
- The role of consumers;
- Obstacles and
- Data collection and dissemination.

By 2012, a total number of 281 smart grid projects had been identified all over Europe—the 27 European Union Member States (EU-27), Croatia, Switzerland and Norway. These projects generated roughly € 1.8 billion in investment in 2012. Among the EU-27 countries, Denmark invests the most in research and development by supporting small-scale and medium projects, while UK, Germany and France are the foremost investors in smart grid projects (both demonstration and research and development projects) [6].

The percentage of projects with a budget greater than € 20 million, considering all the smart grid projects in JRC's catalogue, has increased steadily from 27% in 2006 to 61% in 2012. Continued uncertainties about the business case for smart grid applications and how costs and benefits will be shared among participants are factors that limit private investment. Public sector funding plays a crucial role in stimulating private investment in smart grid R&D and demonstration projects [6].

In terms of investments, distribution system operators (DSOs), utility and energy companies are the best represented in all projects and then universities, research centres, manufacturers and IT/telecom companies followed. The smart grid landscape is quite diverse, with several types of organisation participating to a significant degree in smart grid projects [6].

The following lessons can be learned from smart grids applications in Europe:

- New intelligent control and automation systems are becoming popular for improvement the controllability and monitoring the capacity of the grid and are making it increasingly possible to host distributed energy resources (DER);
- Projects that focus on distributed ICT architecture to coordinate distributed resources and provide flexibility of demand and supply are possibly in the majority;
- The current attention being given to integrating electric vehicles (EV) into smart grids is to ensure that the charging and communication infrastructure works properly, rather than as a means to test vehicle-to-grid (V2G) services;
- It seems that there are increasing interests on storage. Most of the projects started in 2012 use energy storage as an additional source for the flexibility of grid.

In the light of smart grid projects and applications done in the Europe, as mentioned above, It is understood that the smart grids

attract system operators and consumers due to being more efficient, flexible, reliable, renewable and integrating variable energy sources into grid by providing wide range of information and control to users over the system [7,8]. Based on the lessons learned in The Europe, modernizing transmission and distribution networks in Turkey is essential for smart grid evolution. Therefore, the extension of Turkish distributed and renewable energy generation will be grown at least 30% by 2023. Moreover, integration of wind requests additional organization strategies for power systems. In order to manage these strategies, smart metering equipment, switchable network and storage facilities and full active power management seem to be remarkable alternatives for Turkish smart grid system. The key issues in smart grids are the real time communication and remote control. Moreover, the cyber security has become a significant topic in smart grids. Finally, Turkish Government has to take the several necessary legislations and provide the satisfactory encouraging regulations for investors at private generation and distribution level [8].

3. Advantages, drawbacks and the policy of EU from the current smart grid installations in Europe

Three aspects, which are environment, security, power quality and market, have been attributed by the experts and researchers of smart grid development of Europe [9–11]. Since the significance of environmental protection and interconnection of renewable energy to the grid gained great attention, main issues of the European smart grid have been moved to the interconnection of the renewable energy and distributed generation, providing reliable, quality and the value-added services of grid to all customers [11].

It is 2020 target of European Union to reduce greenhouse effects by 20%, increasing the interconnection ratio of renewable energy to grid by 20% and increasing the energy efficiency by 20%. Ensuring sustainable, economic, and secure power supply by the use of the innovative products and services, smart monitoring, control, communications, self-restorative technologies are the aims of European smart grids proposed. The other targets to be achieved can be compatibility among the operation and action of the generation side, the customs and the members who have both the characteristics of power providers and consumers.

The European Network of Transmission System Operators (ENTSO) and the European Network Distribution System Operators (EDSO) published a smart grid benefits assessment system based on the above description of the smart grid, which divides the benefits of smart grids into nine parts, as shown in Table 1 [11]. The function of this assessment system is to evaluate and develop effective and efficient smart grid technologies, to assess the benefit of the smart grid projects and to select more effective and more efficient projects.

Drawbacks of the smart grids in Europe are lack of non-technical issues of interoperability and standards, which can be policy-related, social or regulatory matters. Indecision about roles and responsibilities in new smart grid applications, hesitation on sharing of costs and benefits and consequently over new business models can be underlined as regulatory barriers. Moreover, the variety of regulatory activities in Europe might present substantial barriers to the replicability of project results in different countries. To support the transition to a smart grid, sharing project information is crucial. However, there are many obstacles to retrieve web information on projects such as non-existing a dedicated web site and using national languages for existing web sites. In addition, the smart grid projects and investments are not homogenously distributed through Europe. A few countries are bteer in terms of spending. As the UK's represents 15% of the total, Germany's and France's 12% each and Italy's, Denmark's and Spain's 10% each [6].

4. History of the Turkish electricity market

People started using electricity in their daily lives in 1878. The first public power plant was put into operation in London in 1882. Hepbasli [12] reports that the first Turkish electrical generator was a 2 kW dynamo connected to a water mill in Tarsus, Turkey, in 1902. Hepbaslı also reports that the first large power plant was installed in Silahtaraga, Istanbul, in 1913. Since then, the following have been the main developments in the Turkish electricity market [12,13]. The electricity industry was heavily dependent on foreign investment, which flowed into the country as it sought to develop a liberal economy between 1923 and 1930. Primarily German, Belgian, Italian and Hungarian companies provided electricity in Turkey. The first Turkish electricity company, ‘Kayseri ve Civari Elektrik Turk Anonim Sirketi’, was established in 1926 [14]. The 1930s demonstrated the beneficial effects of public ownership, as the global electricity industry was restructured.

A 5-year industrial plan was implemented by the government in 1933 which was significant active role of the government in the electricity industry. It started out by seeking out hydro and thermal sources for power generation. This initiation was followed to publish some legislation to allow the municipalities to build and operate power plants. In 1935, the Electrical Energy Resources Survey Administration (EIE) was founded; later on the Bank of the Provinces and State Hydraulic Works (DSI) were established. The government's development plan was more of a national policy than a global one. The Ministry of Energy and Natural Resources of

Table 1
EU smart grid benefits assessment system.

Benefits	Indicators
Increased sustainability	CO_2 reduction
Adequate transmission/distribution grid capacity to bring the electricity generated from all sources to consumers	Distributed power capacity, maximum accommodate power injection, etc.
Harmonization and standardization of grid connection procedures giving access to any type of grid users	Reduce the time of new users connecting to the grid, unified custom access standard
Higher security and quality of supply	Peak load clipping rate, improve the prediction and control of emergency efficiency
Enhanced efficiency and better service in electricity supply and grid operation	System losses reduction, the improving the system reliability
Effective support of pan-European electricity markets by load-flow control to alleviate loop-flows and increased interconnection capacities	The improvement of cross-tie line capacity
Coordinated grid planning and development involving joint European, regional and local grid	
Cost efficiency of the deployed solutions	
Enabling of new business models and the development of innovative products and services	

Turkey (MENR), which was responsible for Turkey's energy policy, was established in December 1963. This was followed by the passing of a law creating the Turkish electricity monopoly, the Turkish Electricity Administration Commission (TEK).

All generation power plants, transmission lines and distribution facilities were transferred to a single state economic enterprise, the Turkish Electricity Authority (TEK), which was granted a legal monopoly for the generation, transmission, distribution and retail sale of electricity.

The institutional structure of the Turkish electricity market, characterised by a high level of centralisation and state control (as was also the case in Europe at that time), was inspired by global trends in the restructuring of electricity markets and by technological improvements that allowed small-scale power plants to be built, which led to more efficient and cheaper energy generation. But after only twelve years, TEK's legal monopoly was broken up in 1982 and TEK was split into separate generation, transmission and distribution companies [15]. As seen in Fig. 1, TEK maintained its vertically-integrated structure until 1993, when it was unbundled by government decree into two state economic enterprises: the Turkish Electricity Generation and Transmission Co. (TEAS) and Turkish Electricity Distribution Co. (TEDAS). In 2000, the generation and transmission markets were further separated and TEAS was divided into three state economic enterprises: the Electricity Generation Co. (EUAS), the Turkish Electricity Transmission Co. (TEIAS) and the Turkish Electricity Trading and Contracting Co. (TETAS). TEDAS was further reorganised and 21 affiliates were established in accordance with the privatisation agenda of the Turkish Privatisation Administration [15].

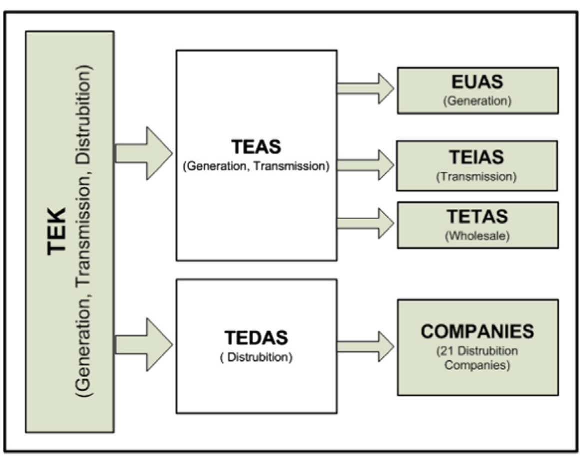


Fig. 1. The historical development of Turkish electricity market structure.

It was deemed necessary to establish a financially strong, stable and transparent electricity market, with competitive and specific laws in order to ensure a sufficient, high-quality, continuous, low-cost and environmentally friendly supply of electricity to consumers and to maintain an independent regulatory and supervisory framework. The new law covered the generation, transmission and distribution, and the wholesale and retail sale of electricity and related services. It also covered electricity imports and exports and the rights and responsibilities of all entities connected with those services. It established a Regulatory Body of the Electricity Market and sets out the procedures and principals underpinning that body. The law also established the procedures to be followed for the privatisation of electricity generation and distribution assets [12,13].

Milestones in the reform of the Turkish electricity market are set out in Fig. 2 [13].

5. Smart grid opportunities in Turkey

Turkey has 21 electricity distribution regions, run by 21 electricity distribution companies, including 13 private companies—Akedas, Aydem, Baskent, Camlibel, Coruh, Firat, Kayseri, Meram, Osmangazi, SEDAS, Trakya, Uludag, and Yesilirmak and eight state-owned companies, which are currently being privatised, namely AnadoluYakasi, Aras, Bogazici, Dicle, Gediz, Goksu, Toroslar and Van Golu Electricity Distribution Companies (DISCOs), as illustrated in Fig. 3. The privately-owned distribution companies serve 52–53% of Turkish customers, corresponding to 55% of electricity consumed, according to figures from the end of 2011. The Turkish government earned approximately USD 6 billion in revenues from the privatisation of 13 regional companies.

On average, 16% of electrical energy in Turkey is lost or stolen (the “loss and theft ratio”). Uludag DISCO has the lowest loss and theft ratio at approximately 7%. Dicle has the highest ratio at approximately 61%. Turkey needs to introduce smart metering to

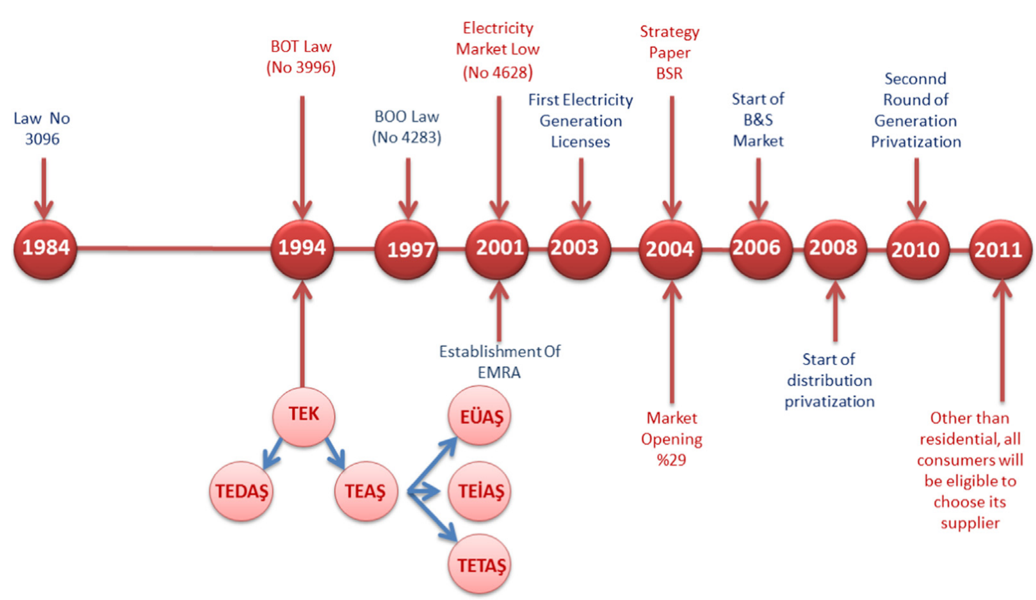


Fig. 2. Milestones in Turkish electricity market reform.



Fig. 3. Twenty one Electricity distribution regions in Turkey.

Table 2
National Official Documents Laws and Rules in Turkey [17].

National Official Documents, Laws & Rules		Turkey
National strategies, energy targets & strategies and transition paths	Available	• The Republic of Turkey Ministry of Energy and Natural Resources Strategic Plan (2010-2014)
Laws and Rules in the energy sector that have implication on Smart Grids	Available	• Electricity Market Grid Regulation, • Transmission System Supply Reliability and Quality Regulation, • Electricity Market Balancing and Settlement Regulation, • Communique Regarding the Principles and Procedure of Financial Settlement in the Electricity Market, • Communique Regarding the Meters to be used in the Electricity Market, • Electricity Market Import and Export Regulation • Communique Regarding Regulation of Market Management Revenue

Table 3
R&D Framework, Programs & Policy Documents in Turkey [17].

R&D Framework, Programs & Policy		Turkey
R&D framework for research in smart grids? if not R&D framework for energy research in smart grids? if not, R&D framework in general	Available	• R&D Framework in Legislations; Supreme Council for Science and Technology, • IEA Report Turkey 2005, • 9th Development Plan
	Later	• Renewable Energy Act (beginning 2011)
R&D Programs	Available	• Support Programs for Research/Education Communities • Technology and Inovation Funding Programs • Industrial Thesis Supporting Program SAN-TEZ (Turkish) • Supports of Technology Development Foundation (TTGV)
R&D and Innovation policy, Innovation Agenda, Technology Roadmaps	Available	• Vision 2023 Program

reduce losses and thefts in distribution; to increase the quality of supply and efficiency; and to solve the problems encountered in operating day-ahead and balancing markets.

By 2015, over $ 5 billion is due to be invested in smart grid systems [16].

All distribution companies have targets for dealing with technical and non-technical losses. These targets are set to create incentives to reduce the level of losses. If they can reduce the level of losses below the targets, distribution companies can earn higher profits than the regulated profit.

In 2011, overall losses stood at 16%, of which technical losses were represented by 7–8% and non-technical losses were represented by 8–9%. The aim is to reduce overall losses to 10% by 2015.

In accordance with the smart grid investment programme imposed on the DISCOs by the Energy Market Regulatory Authorities (EMRA), the DISCOs were due to invest in their SCADA (supervisory control and data acquisition) systems and in their GIS (geographical information systems) by the end of 2012. The costs of these investments were covered by budgets approved by the EMRA.

However, some delays are expected to occur. EMRA's general approach to smart grid system investment is that it is an innovative sector; hence there is no need to restrict and direct the market development with strict regulations. EMRA sets the minimum criteria and allows the distribution companies to make the necessary adjustments for their own systems. It uses incentive-based regulation to deliver optimal solutions.

Turkey has two interconnection points with the East European Transmission Grid. The test period for synchronous parallel operation of the Turkish and European power systems started on 1 June 2011 and ended in September 2012. For the moment, trade is being limited to 400 MW from Bulgaria and Greece to Turkey and 300 MW from Turkey to Europe via these countries.

TEIAS currently has following actions regarding smart grid applications:

– 1 national control centre (Ankara);
– 1 emergency national control centre (Ankara);
– 9 regional control centres;
– Over 200 remote terminal units (RTUs); and
– Approximately 12 remotely controlled substations

The following systems offer the best prospects for a smart grid in Turkey;

- Automated meter reading systems (AMRS);
- Supervisory control and data acquisition (SCADA) Systems;
- Geographical information systems (GIS);
- A wind power management system capable of managing up to 20,000 MW, as required by TEIAS;
- Primary and secondary reserve control systems, as required by TEIAS;
- Data communications systems and network;
- Communication control centres;
- Wind energy grid management systems;
- Wind generation forecast, wind generation monitoring, static analysis and dynamic analysis systems;
- Primary and secondary frequency control, instantaneous demand control (load shedding: how much, how, automatically) and reactive power control systems;
- A protection control centre;
- Solar energy grid management systems;
- Solar generation forecast, solar generation monitoring, static analysis and dynamic analysis systems.

6. The current state of the smart grid policy in Turkey

One important strategic document about the smart grids policy in Turkey is the Ministry of Energy and Natural Resources Strategic Plan (2010–2014). One of the formulated aims within this strategy e.g. is "Increasing the share of the renewable energy resources within the energy supply". But it is not stated in detail, which role Smart Grids has or could have to reach this goal [17]. A series of legal documents relevant in the smart grids context and R&D Framework are summarised in Tables 2 and 3, respectively.

R&D support programs related to Smart Grids are the Research/Education Communities Programmes and the Technology and Innovation Funding Programs. TUBITAK has a National Research Infrastructure Information System with detailed project information. But no public access to the database is foreseen. The institution mainly dealing with Smart Grids issues is the Turkish Electricity Transmission System Operator TEIAS [17].

6.1. SWOT analysis of smart grid infrastructure in Turkey

SWOT analysis has been done considering the potentials of Turkey, specially relating to the current scenario, barriers and what needs to be achieved for better smart grid infrastructure in Turkey is given in Table 4 [18–20].

7. Expected benefits of smart grid

Automatic controls can help reduce the number of failures, increase the durability of the lines and cut the number of interruptions. Relaxing the system, enabling the system to reach a more stable state and balancing the peak hour demand are the benefits that could be obtained through bi-directional energy flow that would enable consumers to contribute as producers. In addition to offering many advantages to consumers, producers and all units associated with the energy problem would gain from increased market activity.

Table 4
SWOT analysis of smart grid infrastructure in Turkey.

Strengths	Weaknesses
• Large capacity of electric power transmission lines and connections to neighbouring systems • Progress made in implementing the legal legacy of the EU and international agreements (deregulation and liberalization of the sector, horizontal integration, etc.), particularly in the electricity sector • The tendency for technological change and novelty • The influence of energy ministry on the studies for the international cooperation projects	• Lack of Policies and Regulations about Smart Grid • Lack of Consumer Awareness about Smart Grid • Collaborations between Government and Private Sector for Smart Grid Development • Research and Development Trends in Smart Grid Technologies in Turkey • Lack of cooperation and coordination among public institutions and organizations
Opportunities	**Threads**
• R&D programs and Investments undertaken by the Government to support Smart Grid • Growth in the Renewable Energy is Expected to Modernize the Grids • Research and Development Trends in Smart Grid Technologies in Turkey • Construction of new power plants (thermal and hydro, renewable, small power plants) • European Union accession process and harmonization studies	• Lack of interest from main stakeholders e.g. end-users • Too many initiatives undertaken which may result in chaos and lack of co-ordination • Individual, not harmonized actions of main stakeholders • Lack of Government and Private Sector Collaborations in Smart Grid Development • Lack of Research and Development Trends in Smart Grid Technologies in Turkey • Cyber security remains the topmost concern for smart grid applications.



Fig. 4. Main Rivers in Turkey [24].



Fig. 5. Distribution network monitoring and control.

Within the scope of European Union's 20-20-20 target, the greatest contribution to the reduction of emissions will be through increased utilisation of renewable energy. Due to the importance of smart grid technologies in connecting more renewable energy to the network, the EU established the European Union Smart Grid Technology Platform in 2006.

Europe has set out the vision and the strategy for the network structure in the future. The vision for the smart grid is given as a 'presentation of new products, processes and services; increase in the productivity in industry; increase in the competitiveness of Europe in the global market by using cleaner energy sources'. The vision for smart networks set out by EU indicates that the smart networks will play a leading role in helping reach EU's economic and environmental objectives. Considering Turkey's connection with the European network of transmission system operators for electricity (ENTSO-E), it is clear that Turkey's grid system has to adapt to this change and complete its infrastructure.

Frequency control in energy production is achieved through balancing demand and supply. This demand–supply balance is achieved in coordination with TEIAS. Increases or reductions in frequency are indications of disruptions to the energy produced and consumed. The balance of the produced and consumed energy is obtained by switching the resources on and off using SCADA. It is better if the frequency can be balanced more quickly. Since the reaction speed in old systems is low, work is ongoing to bring these systems up to date [21,22]. In the future, the balance in the system will be bidirectional, through both production and consumption [23]. In addition the above-mentioned routine steps, smart grids can help bring about self-managing systems. Some of the parameters to be taken account when applying smart grids include minimising technical losses by putting the power plant closest to the consumption area; the need to supply the cheapest energy in the market; establishing which parts of the current power plants are having adverse effects on the network; and giving higher priority to renewable energy.

The government is trying to promote the use of hydro, renewable solar and wind energy with a view to cutting carbon emissions. Solar panels are not widely used in Turkey due to their high cost. After the cut in the price of the solar panels, it is assumed that each consumer will be connected to the network as a producer. Wind power plants are much cheaper than solar panels, but the lack of continuity of wind is an obstacle in the widespread use of wind power plants. In addition to this, Turkey has the potential to provide an overall figure of 430 terawatt hours (TW h) of natural hydropower, which is about 1.1% of the global and 13.75% of the European potential. However, only about 30% (130 TW h) of that potential is deemed to be economically feasible. Recent investigations of small hydroelectric power plants assume an additional economical energy potential of 38 TW h per year. About 97% of this economic potential is located on 14 river basins out of 26 rivers in Turkey. The main rivers in Turkey are shown in Fig. 4 [24]. Most of them are located in Turkey's eastern regions. Basically, the Euphrates and the Tigris River with their far-ranging watershed areas and higher elevation contribute to the country's abundant potential, enabling large power plants to be built. In addition, small power plants on rivers at lower elevation and with smaller drainage areas, mostly situated in the western areas, are suitable for producing electricity.

The Turkish General Directorate of Renewable Energy was established in November 2011 to promote the use of renewable energy sources and to carry out some tasks related to renewable energy. These include:

- Identifying and evaluating all of Turkey's sources of renewable energy such as hydro, wind, geothermal, solar, biomass and other renewable energy sources;
- Carrying out pilot projects to assess the accuracy of measurements;
- Collaborating with local research institutions and non-governmental organisations to develop pilot systems;
- Carrying out publicity and consultation activities;
- Raising awareness about the use of energy-efficient buildings,
- Continuing to collaborate with industry;
- Implementing energy efficiency projects approved by the Energy Efficiency Coordination Board, and monitoring and supervising research and development projects;

- Evaluating studies and developments in the fields of renewable energy, the needs and requirements of the country in accordance with the objectives and priorities;
- Projecting sources of renewable energy sources and making recommendations.

Since Turkey and Europe have different grid structures, both smart systems and renewable energy sources should continue to be assessed and the most appropriate conditions investigated. The Turkish grid should also establish dynamic analysis infrastructure. In addition to examining the load flow and short circuit contribution made by renewable energy sources such as hydro, wind and solar energy, their dynamic structures should also be examined [25].

Frequency control is one of the most important issues in energy transmission. A smart grid system is exemplified by its ability to control the frequency by responding to spontaneous energy demand and holding energy in reserve. If a line is overloaded, a smart network application excludes a unit automatically. In cases of tertiary frequency, plants are operated by keeping them ready to respond to day-ahead estimates. This is done manually. Obtaining information remotely on oil in the transformers and on relay locations can be considered as a part of a smart network [21]. A smart network system can help to identify how close energy consumption is to current energy sources, reduce technical losses in the network and make the load control of the energy transmission line more responsive. In the event of a failure on a line, since the lines are fed by more than one supply, a smart network system would allow the power to be cut without the subscriber being aware of it.

In low voltage distribution networks the voltage values in the transformers can be read with the help of SCADA. The power can be turned on and off remotely from Konya and Ankara. The meters can be read remotely on an ongoing basis. Although these operations cannot exactly be considered as a smart network system, they do constitute elements of a smart network [26]. There is a gradual tendency towards creating a smart network system. Fig. 5 shows distribution monitoring and control room.

Meter applications have many benefits. Automatic meter reading (AMR) system applications were first used to measure consumption and billing. They also offer many opportunities to improve energy quality and reliability by analysing aspects of the network, including current and voltage information, phase imbalances, harmonic values, sinusoidal waveform records and database applications. TEDAS's minimum requirements as regards electronic meter compatibility are that they should meet the IEC standards or be compatible with the corresponding TSEN standards (IEC 61036, IEC 61 268, IEC 61107, IEC 687, IEC 1038 and other standards).

In addition to above benefits, monitoring the system can help detect technical losses, find illegal or unmeasured use of energy, identify if meters are wrongly connected, if the wrong multiplier factor is being used or if the meter has broken down, and can find mistakes in energy consumption readings and other possible problems.

AMR provides faster and accurate meter reading and data collection for the distribution companies. Annual operating costs can be reduced. Smart meter reading can help save time and reduce the number of personnel needed. Moreover, smart metering gives statistical information about different consumer groups such as industrial customers, farms, homes, commercial properties and public institutions. AMR applications on smart meters allow different features to be offered to different subscribers. One of these is the multi-tariff application, which helps consumers to time their energy consumption to help cut energy consumption during peak hours.

Smart grid systems allow most routine procedures in the distribution system to be done, such as allowing reactive loads on the network to be built up smoothly, and evening out capacity. They allow systems to be repaired quickly and can implement controlled power cuts in case of failure. If one of the lines fails, the location of the fail is identified immediately and teams dispatched to deal with it. Customers are informed of the situation. Since the quality of the power is inspected routinely, the system can be controlled. Many such processes are done with smart grid systems [27].

With regard to medium voltage energy, using breakers and switches will increase the continuity of supply considerably [28]. Distributed energy production (DEP) appears to be a style of technology production, however, it is a means of planning and operating the electricity network. Integrating DEPs within the scope of a plan will make the interconnected Turkish system more robust and reliable [29].

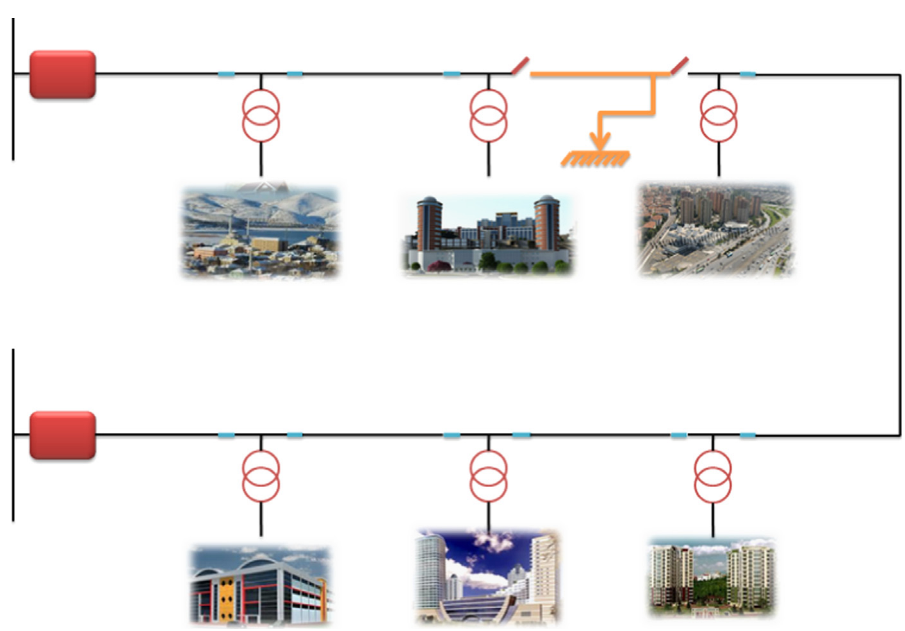


Fig. 6. Double feeding, or ring, grid.

Knowing in advance about potential breakdowns in a network will help managers to take the necessary steps to ensure that consumers are not left without energy. In a ring network, as depicted in Fig. 6, a system is established to ensure continuity of the energy supply to consumers if a short circuit has occurred at any point. After the occurrence of the short circuit, instead of cutting off the energy to the whole network, a signal is sent to the relevant circuit breaker. The continuity of the energy supply is guaranteed by turning off the circuit breakers that had been turned on before the fault occurred [30].

Automation and decision support systems are increasingly being used to identify individual faults in the network. Society will certainly benefit if governmental bodies and institutions avail of geographic information systems in formulating their policies [31].

8. Conclusions

In order to provide a stable, low-cost, reliable, efficient, robust, sustainable and environmentally friendly electrical energy system to consumers, a fully operational smart grid system needs to be established in Turkey.

A smart grid system would provide the following advantages and accelerate the full integration of the Turkish grid system with that of Europe:

- Increase the quality and efficiency of supply;
- Solve problems encountered in running day-ahead and balancing markets;
- Enable frequency control by responding to spontaneous energy demand and holding energy in reserve;
- Reduce technical losses in the network and thefts;
- Enable more responsive load control of the energy transmission line;
- Allow power to be cut off and turned on remotely;
- Enable grid energy transmission capacity to be increased by reducing losses and controlling the active and reactive energy transmitted;
- Help policy makers, transmission system operators, and end users to prepare day-ahead plans;
- Improve the ease with which the grid can be overseen and controlled;
- Increase capacity to host distributed energy resources (DER);
- Increase the ratio of using renewable energy in the grid,
- Provide flexibility in demand and supply;
- Integrate electric vehicles (EV) into smart grids ensuring that the charging and communication infrastructure works properly rather than testing vehicle-to-grid (V2G) services;
- Enhance the use of storage systems as an additional source of grid; and
- Improve collaboration between companies, universities and consumers.

If classical grids in Turkey were transformed into smart grids, not only would the above-mentioned benefits be achieved, but Turkey would be able to attract huge amount of investment and boost its economy. The Turkish grid system would then be a powerful player in the energy market in Europe.

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